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EVALUATION OF THE GROUND WATER RESPONSES TO ARTIFICIAL RECHARGE OF RAINWATER IN SELECTED ALLUVIAL AQUIFERS

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ABSTRACT

Groundwater is an extremely important water resource and due to over exploitation of groundwater for irrigation and other purposes, especially in dry climates and in areas which are facing water stress, has led to irreversible consequences. Shallow groundwater resources are often of poor quality and above that they are harshly over-exploited. Therefore, it is the problem which is to be taken into prior consideration and Artificial recharge is expected to become necessary in the future as growing populations require more water, and as more storage of good quality water is needed for use in times of water shortage. This study is conducted at the micro level in the Campus of Panjab University, Chandigarh which is also facing problem of water logging and shortage in the region. Around 21 observation sites has been selected and water level is recorded on monthly basis following the Water Level Fluctuation Method to check the groundwater response to artificial recharge. In the study area, installation of artificial recharge structures served the deeper aquifers and helped to maintain the water level fluctuation variations more stable.

KEYWORDS: Artificial Recharge, Shallow Groundwater Resources, Water Logging, Water Level Fluctuation

INTRODUCTION

Groundwater is an extremely important water resource, as it comprises more than 98% of the entire world's liquid fresh water (Bouwer, 1978). Over exploitation of groundwater for irrigation and other purposes, especially in dry climates and in areas which are facing water stress, has led to irreversible consequences. The ever-growing population, rapid industrialization and increased water demand for agricultural production in numerous countries require much more water of adequate quality to suffice their needs. Overexploitation of groundwater in several parts of the country has resulted in declining groundwater levels, a reduction in supply, saline water encroachment, drying of the spring and shallow aquifers, increased cost of lifting, reduction in free flow and even local subsidence in some places (Singh and Singh, 2002). In many regions there is a lack of surface water resource and the water bearing sub-surface zones are having severe water contamination. Shallow groundwater resources are often of poor quality and above that they are harshly over-exploited. The decreased microbiological quality of the water may cause public health outbreaks of diarrhoeal disease, a significant disease burden in developing countries today (Gadgil 1998).

The type and extent of chemical contamination of the groundwater largely depend on the anthropogenic activities mainly by acid rains, fertilizers, industrial waste, garbage and domestic waste (Kaushik and Kaushik, 2006), the geochemistry of the soil through which the water flows prior to reaching the aquifers (Zuane, 1990). Therefore, it is the problem which is to be taken into prior consideration and all the proved water techniques along with managerial strategies shall be adopted that could help to reduce the prevailing disaster. To meet the demand, reliance on ground water has been

rapidly increasing, especially, in the arid and semi-arid regions like India, where the current ground water potential (43.2 M ha-m) needs to be judiciously utilized (Singh, 1997). Although methods like rain-water harvesting and artificial groundwater recharge have been extensively implemented in the developed countries from several decades, but their use in developing countries, like India, on vast scale has occurred only recently. Natural recharge of groundwater occurs through varied water inputs into the soil in the form of precipitation and infiltration from streams, lakes, or other natural water bodies and its discharge occurs naturally and artificially by different outputs such as evapotranspiration, runoff and groundwater extraction.

The groundwater table is declining at a very fast rate in many parts of India. In some places it has gone beyond at such a depth below ground that it is not economical to pump water forcommercial and non-commercial purposes and even Government has banned digging of ground water extraction systems in considerable number of states in India. Withdrawal of groundwater is not only responsible for declining trends, the scanty and low rainfall resulting in meager monsoon is equally responsible. Majority of the ground water stress areas categorized as overexploited and critical units also lies in such states.

Artificial recharge, as defined by the Central Ground Water Board (CGWB) of India, is a process of augmenting a groundwater reservoir at a rate that exceeds natural conditions of replenishment (CGWB, 2003). Artificial recharge systems are engineered systems where surface water is transferred directly in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources (Bouwer, 2002). In the present scenario, due to urbanization most of the land is covered with streets, roads, roofs, and other impermeable surfaces that produce more runoff and have much less evapotranspiration than the natural surfaces. With urbanization, more runoff is produced, which can be collected for on-site storage and artificial recharge, or it flows naturally to ephemeral streams where it infiltrates into the soil and moves down to the groundwater (Lerner, 2002). To reduce the reliance of water supplied by the utility companies and water authorities, a number of authors have reported rainwater recovery and reuse systems for different buildings (Fewkes, 1999; Dixon et.al., 1999; Mikkelson et. al.1999; Hills et. al., 1999). Artificial recharge is expected to become necessary in the future as growing populations require more water, and as more storage of good quality water is needed for use in times of water shortage. In this paper, we report a study undertaken in an educational institute in Chandigarh, to have better understanding of thegroundwater dynamics in relation to artificial recharge of rainwateroccurring in different aquifersin that area.

PURPOSE AND SCOPE

This paper documents a comparative analysis of the effects of local precipitation patterns on existing water-level records from different sampling sites located in various hydrogeological settings in Panjab University Campus, Chandigarh (Figure 1). The locations were chosen such that every well in the area is almost at similar depths and altitude also receives similar precipitation while experiencing notably different levels of ground-water development. The response of ground-water levels to precipitation patterns for records from 21 sampling sites from different regions in Panjab University Campus is evaluated.

DESCRIPTION OF STUDY AREA

The study area for this work is the campus of Panjab University, which is located at sector-14 Chandigarh, Punjab, India. It is located in North Western part of the Chandigarh. The total land area of Sector- 14 is 15, 60,840sq.m.out

of which undeveloped area is 38,000 sq. m., while road and footpath covers an area of 1, 40, 000 sq.m. Open space and lawn area is 10, 49, 840sq.m, whereas, area covered by the buildings is 3, 33, 000 sq.m. The site map of the study area is shown in Figure 2.

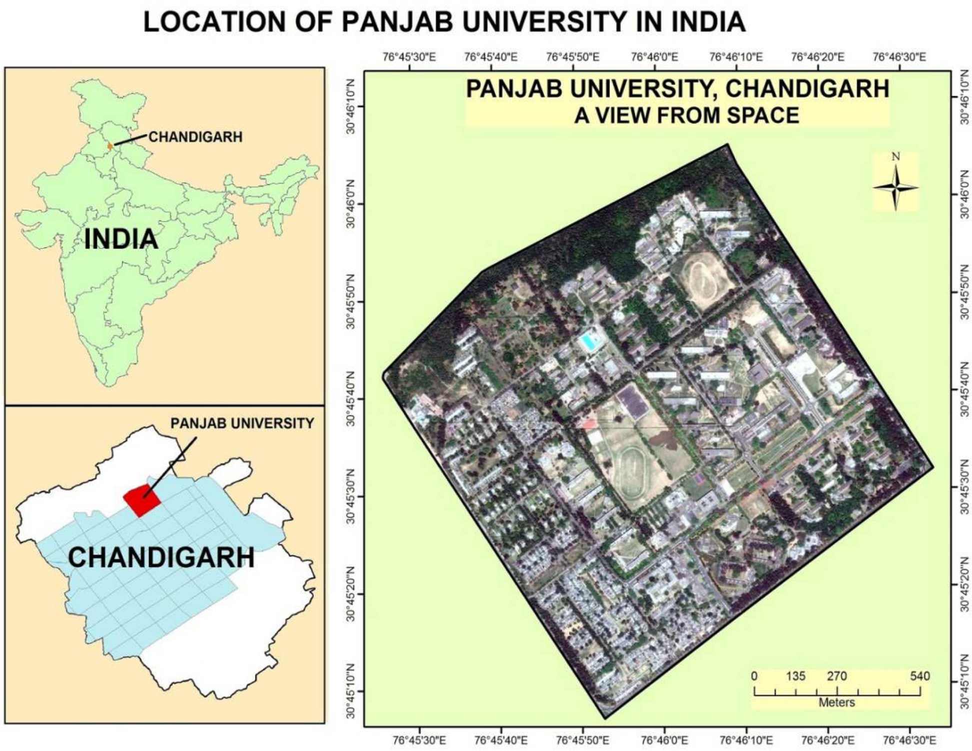

Figure 1: Site Map Showing Location of Panjab University, Chandigarh

Panjab University campus is located at 76^o 45’30’’E to76^o 46’30’’ E longitude and a latitude of 30^o 45’10’’N to 30^{O}46’10”N.The study area has a plain topography with a gentle slope towards the north east to south west direction. The average elevation of the command ranges from 340 m to 360 m from the mean sea level. The ground water levels in the University Campus ranged between 9.75 m and 15.8 m below ground level (bgl) during the year 1990 (CGWB,2003).

SOIL LITHOLOGY

The area of Panjab University Campus is alluvial plain comprising of medium to coarse grained sand. The sub-surface lithology of the Panjab University area as encountered in the bore hole drilled by the Central Ground Water Board near Basic Medical Sciences Block for roof top recharge well is given below in table 1.

Table 1: Sub-Surface Lithology of Panjab University, Sector-14 Chandigarh

Depth Range (mbgl)	Thickness (m.)	Characteristics	Major Sub- Surface Formation
0.00-3.00	3.0	Brownish mixed with gravel	Sand and Clay
3.00-13.72	10.72	Light grey, medium to coarse, mixed with gravels, pebbles and a few cobble.	Sand
13.72-30.48	16.76	Brownish to black in color, hard, sticky and plastic in nature.	Clay
30.48-32.00	1.52	Brownish, fine to medium grained with a few gravels	Sand
Table 1: Contd.,			

32.00-41.15	9.15	Brownish in color, sticky and plastic in nature	Clay
56.70-64.00	7.30	Mixed with fine to medium grained sand, cobble and boulder, composed of sand, stone and quartz and calcareous material	Gravels and pebbles
64.00-73.00	9.00	Brownish and hard sticky and plastic in nature	Clay

(Source: CGWB, 2003)

A number of wells have been dug in the study area during the period of study at different points of time to recharge the groundwater in the confined aquifers system prevailing in the campus. Soil samples were collected at various depths while excavating the bore wells at different stages while drilling bores of 6” diameters for analysis and textural classification. The wells have been dug by using the rotary method with the help of the Central Groundwater Board (CGWB). The lithology of each of the well during its excavation was carefully recorded and the log data for each well was created which has been used for construction of artificial recharge wells.

METHODOLOGY

The Government of India constituted a committee named as Ground Water Estimation Committee which recommended the use of “groundwater table fluctuation method” for sufficient accuracy and hence, it is also adopted for our study area. Because of the simplicity of the method and wide availability of water-level hydrographs from observation wells, the Water Table Fluctuation method has been used for many years (Meinzer, 1923; Rasmussen and Andreasen, 1959; Crosbie and others, 2005). An excellent review of the Water Table Fluctuation method is provided in Healy and Cook, 2002).

Based on the available data and the knowledge aboutthe local hydrogeology, we can choose the most suitable recharge method and estimate the natural ground water recharge (AmithaKommadath, 2000). The impact of theartificial recharge would depend upon four factors likeslope of the area, surface infiltration, thickness of the aquifer and the quality of water (Saravi et al., 2006). The rate of the aquifer recharge is also one of the most difficult factors in the evaluation of the rainwater harvesting of ground water resources (Kumar & Seethapathi, 2002). The Water Table Fluctuation method is best applied for short-term water-level rises that occur in response to individual storms.The method is simple and easy to apply and based on accepting that rises of the water table are due to recharge water reaching the water table (Delin*et al*., 2007).

WATER LEVEL BEHAVIOR

There are two distinct aquifer systems existing in the study area - shallow and deep. Shallow aquifer occurs under semi-confined conditions and exists down to 20 to 30 m below land surface. Deep aquifers below 40 m are under confined conditions. The piezometric head of the deep aquifers stands much below the water table of shallow aquifers. Changes in water levels occur over different time scales. Long-term fluctuations, over periods of decades, can be attributed to naturally occurring changes in climate and to anthropogenic activities (e.g., changes in land usage, pumping, irrigation, and induced infiltration). Seasonal fluctuations in groundwater levels are common in many areas due to the seasonality of evapotranspiration, precipitation, and irrigation. Short-term water-table fluctuations occur in response to rainfall, pumping, barometric-pressure fluctuations, or other phenomena.

WATER LEVEL FLUCTUATION IN THE STUDY AREA

Decline of water level especially in summer season is a common problem not only being faced by Chandigarh but by the whole country itself. In Chandigarh, the area falling in northern regions have remarkable low water levels and observe high fluctuations in relation to seasonal precipitation. Recharge to groundwater is affected by several factors and these factors also pose influence to the groundwater fluctuations. The fall and rise in groundwater level occurs when the discharge exceeds or reduces over the recharge rate. The locations of the groundwater samplingsite are shown in figure 2.

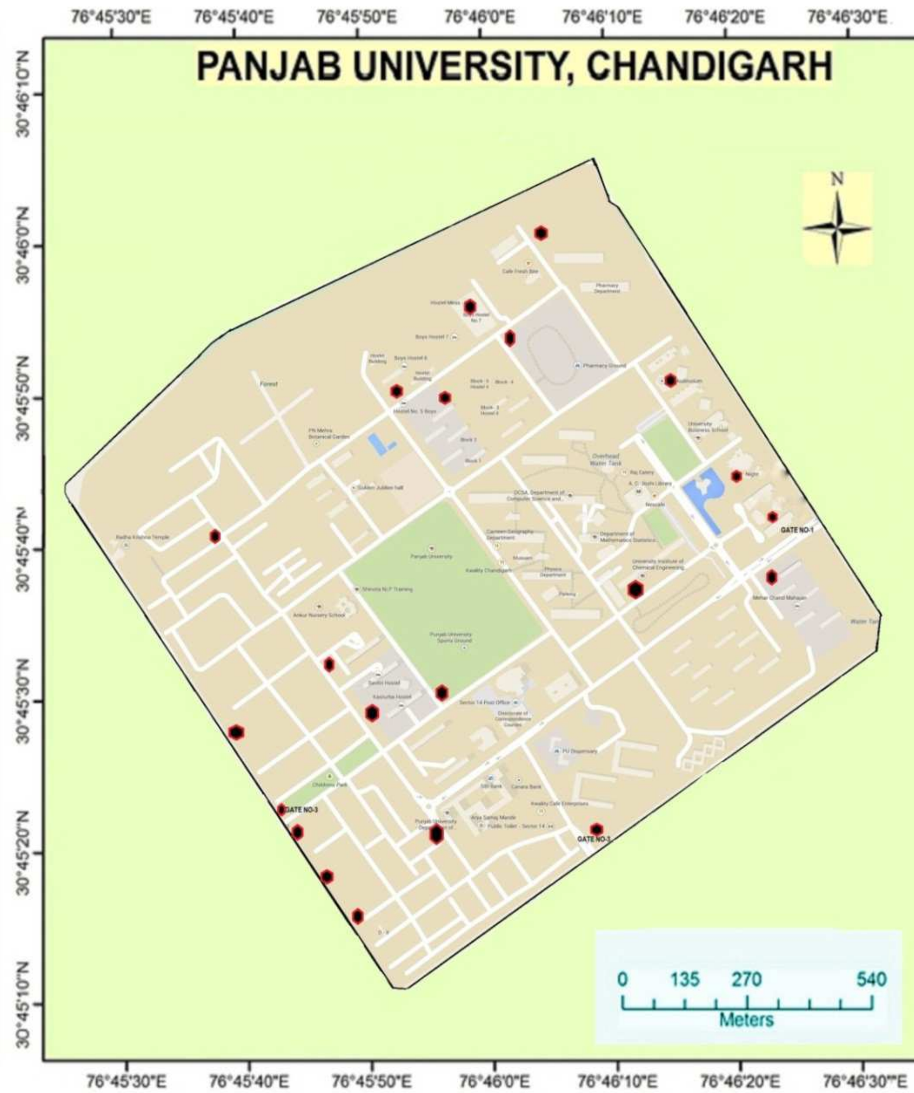

Figure 2: Showing Groundwater Sampling Locations in the study Area

Seasonal Water Level Fluctuations (June 2013 to October 2013)

The study of the seasonal Water level Fluctuation(Table 1) reveals that major part of the study area shows rise in water level during October 2013 when compared with June 2013.The depth to water level varies from 7.5 m to 32.1 m in the areaunder investigation. The seasonal fluctuations varies from 1.5 m to 16.9 m in the area under investigation.

Table 2: Depth to Water level and Seasonal Fluctuation 2013, in the Study Area

Location/Site	Depth to Water Level Fluctuation (m bgl)		Seasonal Fluctuations 2013 (m)
	Depth to Water Level Fluctuation Pre-monsoon June 2013	Depth to Water Level Fluctuation Post-monsoon October 2013	
Site 1	19	15.6	3.4
Site 2	32.1	29.2	2.9
Site 3	31	28.9	2.1
Site 4	10.7	9.2	1.5
Site 5	14.7	12.1	2.6
Site 6	20.8	8.2	12.6
Site 7	21.3	14.3	7
Site 8	30.2	17.1	13.1
Site 9	25.2	17.2	8
Site 10	28	23.4	4.6
Site 11	23.5	7.5	16
Site 12	28.7	11.8	16.9
Site 13	19.8	12.4	7.4
Site 14	17.6	14.3	3.3
Site 15	18.2	14.8	3.4
Site 16	14	5.9	8.1
Site 17	17.2	10.6	6.6
Site 18	17.2	14.1	3.1
Site 19	24.3	21.1	3.2
Site 20	26.1	15	11.1
Site 21	16.4	13.2	3.2

Seasonal Water Level Fluctuations (June 2014 to October 2014)

The study of the seasonal Water level Fluctuation(Table 3) reveals that major part of the study area shows rise in water level during October 2014 when compared with June 2014.The depth to water level varies from 5.2 m to 42.5 m in the area under investigation. The seasonal fluctuations varies from 1.6 m to 7.7 m in the area under investigation.

Table 3: Depth to Water Level and Seasonal Fluctuation 2014, in the Study Area

Location/Site	Depth to Water Level Fluctuation(m bgl)		Seasonal Fluctuations 2014 (m)
	Depth to Water Level Fluctuation Pre-Monsoon June 2014	Depth to Water Level Fluctuation Post-Monsoon October 2014	
Site 1	41	38.5	2.5
Site 2	3.6	**2**	1.6
Site 3	45	42.5	2.5
Site 4	10.9	7	3.9
Site 5	13.5	10.5	3
Site 6	11.1	7.2	3.9
Site 7	10.1	6.6	3.5
Site 8	19.1	15	4.1
Site 9	13.9	6.2	7.7
Site 10	14.8	9.8	5
Site 11	5.4	1.7	3.7
Site 12	13.1	9.3	3.8
Site 13	12.6	8.2	4.4
Site 14	12	8.5	3.5
Site 15	12.8	10	2.8
Site 16	6	4.3	1.7
Site 17	7.5	5.2	2.3

Table 3: Contd.,			
Site 18	13.1	11.3	1.8
Site 19	18.4	16	2.4
Site 20	12.6	5.4	7.2
Site 21	14.3	11	3.3

Annual Water Level Fluctuations (Pre-monsoon, June 2013 to June 2014)

Annual Water level fluctuation has been worked out by comparing depth to water level, recorded during June 2013 and June 2014 (Table 4). The study shows that (15%) of the stations which are located in northern parts show fall in water level. Average fall in the area under study is 12 m. Table 3 showing annual fluctuation for pre-monsoon (June 2013 To June 2014) reveals that the out of 21 sites,fall in water level is most prominent in sites falling in northern region.

Table 4: Depth to Water Level and Annual Seasonal Fluctuations 2013-2014, in the Study Area

Location/Sites	Depth to Water Level Fluctuation (m bgl)		Seasonal Fluctuations (m)
	Depth to Water Level Fluctuation (m bgl) June 2013	Depth to Water Level Fluctuation (m bgl) June 2014	
Site 1	19	41	-22
Site 2	32.1	3.6	28.5
Site 3	31	45	-14
Site 4	10.7	10.9	-0.2
Site 5	14.7	13.5	1.2
Site 6	20.8	11.1	9.7
Site 7	21.3	10.1	11.2
Site 8	30.2	19.1	11.1
Site 9	25.2	13.9	11.3
Site 10	28	14.8	13.2
Site 11	23.5	5.4	18.1
Site 12	28.7	13.1	15.6
Site 13	19.8	12.6	7.2
Site 14	17.6	12	5.6
Site 15	18.2	12.8	5.4
Site 16	14	6	8
Site 17	17.2	7.5	9.7
Site 18	17.2	13.1	4.1
Site 19	24.3	18.4	5.9
Site 20	26.1	12.6	13.5
Site 21	16.4	14.3	2.1

RESULT AND DISCUSSIONS

Chandigarh received 251.5 mm rainfall in the month of June 2013 against its normal value of 120 mm with an overall excess of 110% (India Meterological Department, 2013). Whereas it alsowitnessed 57% lesser rainfall as against normal, as per a report prepared for the period from 1st June to 28th June 2014 by IMD Chandigarh. To meet the increasing demand of water by the locality, it is required to adopt such a suitable technology with updated system which is in harmony with prevailing environment. In the study area, installation of artificial recharge structures served the deeper aquifers and helped to maintain the water level fluctuation variations more stable. By the evaluation of water level data it was observed that, out of 21 sites around 15 sites were among those whose depth in percentage (% age) was much more than 50 %, which means that depth to water level was increased below groundwater level during pre-monsoon season as shown in Figure 3. Also the depth to water levels (%age), of these sites decreased in the post-monsoon period and

maximum sites which were having more water level fluctuation are located in northern region of the study area.

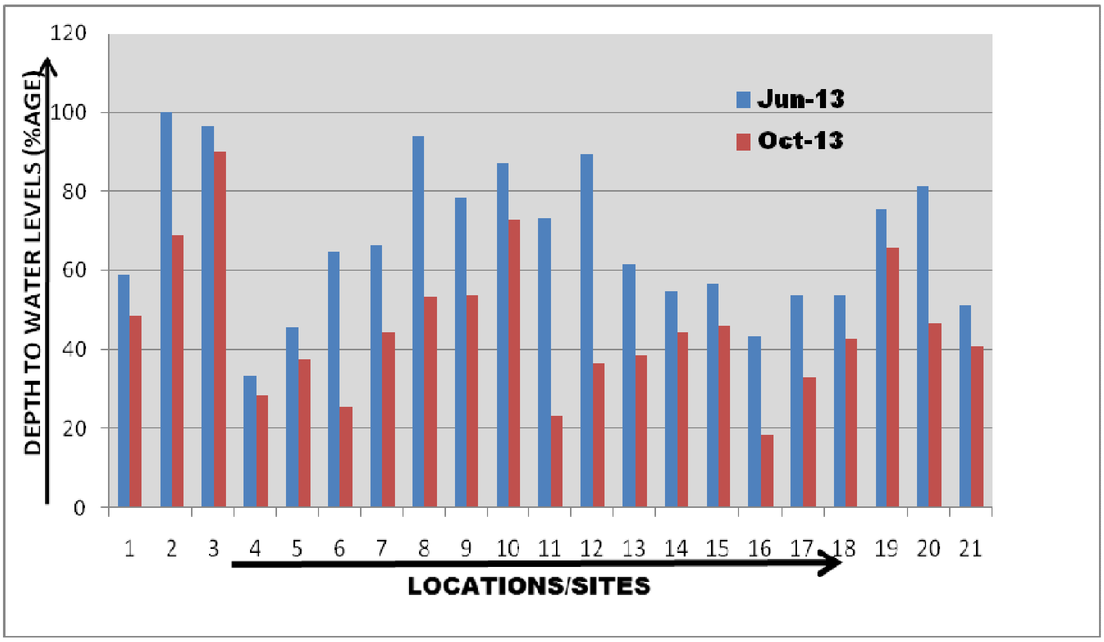

Figure 3: Percentage Variation in Depth to Water level in the Month of June and October 2013

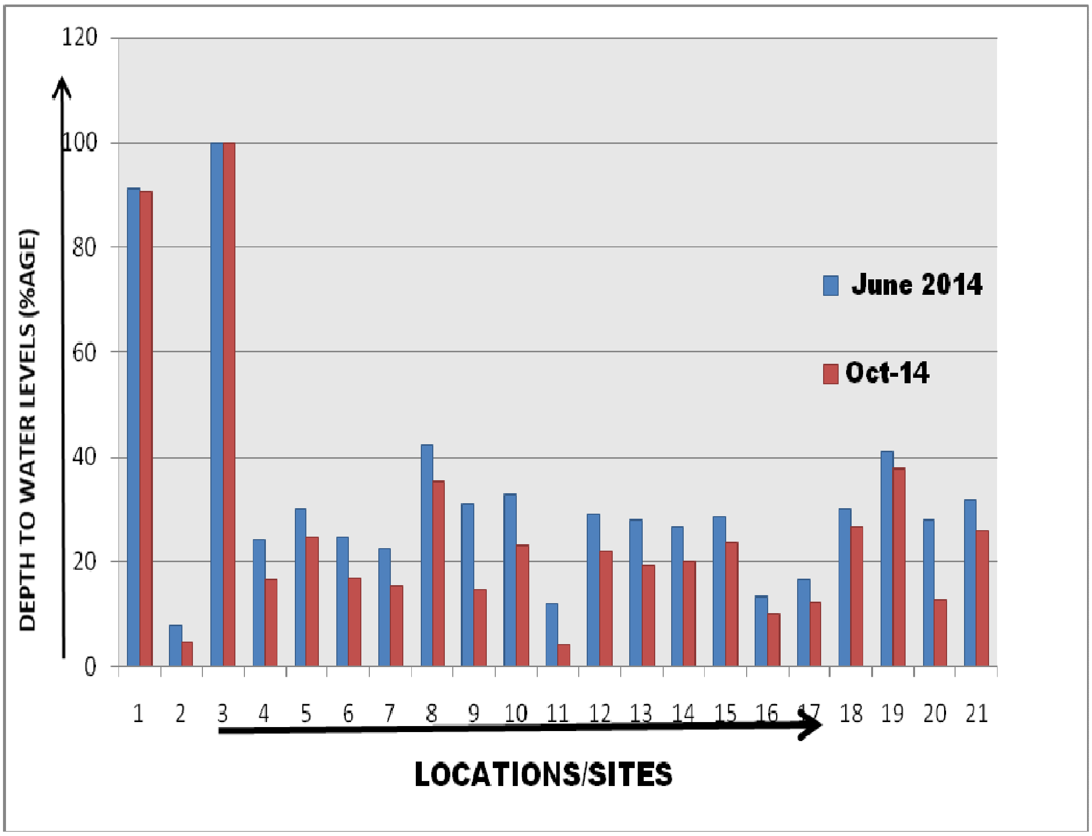

Figure 4: Percentage Variation in Depth to Water level in the Month of June and October 2014

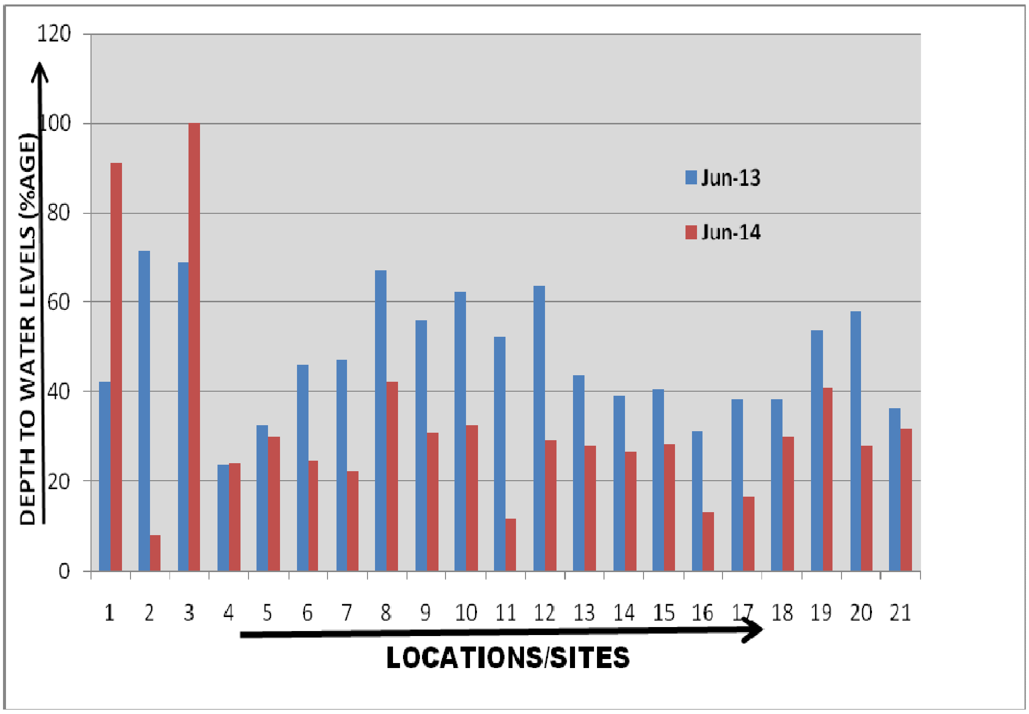

Figure 5: Percentage Variation in Depth to Water level in the Month of June 2013 and June 2014

On comparing the depth to water levels (%age), of pre-monsoon seasons in year 2013 and 2014 as shown in **Figure 5**, the response observed was quiet positive towards the artificial recharge in the study area. Depth to water level has been decreased even after the rainfall received was lesser than 57% against normal rainfall for the same pre-monsoon period.

CONCLUSIONS

The recharge structures established in the Panjab University Campus has been effective in recharging the roof top water harvested and runoff generated from paved areas to enhance recharge wells established in the campus. In a period of one year, the recharge is very effective in increasing the level of the water table in the study area and also some ground water flow appears to take place especially in the northern part of the study area to further downstream.

The present techniques adopted are easy, cost-effective and sustainable in the long term. Though ground water recharge scheme either naturally or artificially may not be the final solution, but they do call for the community effort and create the spirit of cooperation needed to subsequently manage sustains groundwater as a community resource. This study brings to the light the importance of microlevel management of water sources that may influence the sustainable management of water as common property resource.

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